

SECTION 7

STRUCTURAL

7.1 General

This section provides information applicable to the structural design of the Comprehensive Everglades Restoration Plan (CERP) projects. It outlines the acceptable design guidelines to be used, as well as provides considerations and requirements that are specific to these projects. This section is not intended to provide the structural engineer with all data required for design; rather, it is to define the expected level of effort and presentation for these projects.

7.2 References

ER 1110-2-1150, Engineering and Design for Civil Works Projects

ER 1110-2-1200, Plans and Specifications for Civil Works Projects

Stability Design

EM 1110-2-2100, Stability Analysis of Concrete Structures (draft)

EM 1110-2-2504, Design of Sheet Pile Walls

EM 1110-2-2503, Design of Sheet Pile Cellular Structures

ETL 1110-2-352, Stability of Gravity Walls, Vertical Shear

U.S. Department of the Interior, Bureau of Reclamation, *ACER Technical Memorandum No. 11, Downstream Hazard Classification Guidelines*

Wind Design

ASCE 7, Minimum Design Loads for Buildings and Other Structures

Florida Building Code

FEMA 361, Design and Construction Guidance for Community Shelters

Seismic Design

TI 809-04, Seismic Design for Buildings

FEMA 302, NEHRP Recommended Provisions for Seismic Regulations for New Buildings and Other Structures

International Building Code (IBC) 2000

EM 1110-2-6050, Response Spectra and Seismic Analysis for Concrete Hydraulic Structures

FEMA 350, Recommended Seismic Design Criteria for New Steel Moment-Frame Buildings

AISC, Seismic Provisions for Structural Steel Buildings

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Concrete Structures Design

EM 1110-2-2000, Standard Practice for Concrete for Civil Works Structures

EM 1110-2-2102, Waterstops and Other Preformed Joint Materials for Civil Works Structures

EM 1110-2-2104, Strength Design for Reinforced Concrete Hydraulic Structures

EM 1110-2-2005, Standard Practice for Shotcrete

EM 1110-1-2009, Architectural Concrete

ACI 315, Details and Detailing of Concrete Reinforcement

ACI 318, Building Code Requirements for Structural Concrete

ACI Manual of Concrete Practice

Concrete Reinforcing Steel Institute Handbook

PCI Design Handbook, Pre-cast and Pre-stressed Concrete

Steel Structures Design

EM 1110-1-2101, Working Stresses for Structural Design

EM 1110-2-2105, Design of Hydraulic Steel Structures

AISC, Manual of Steel Construction, Allowable Stress Design

AISC, Manual of Steel Construction, Load & Resistance Factor Design

Steel Deck Institute, Design Manual for Composite Decks, Form Decks and Roof Decks

Steel Joist Institute, Standard Specifications and Load Tables For Steel Joists and Joist Girders

American Welding Society, Structural Welding Code-Steel

American Welding Society, Structural Welding Code-Stainless Steel

Aluminum Structures Design

The Aluminum Association, Aluminum Design Manual

American Welding Society, Structural Welding Code-Aluminum

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Masonry Structures Design

TM 5-809-3, Masonry Structural Design for Buildings

ACI 530, Building Code Requirements for Masonry Structures

ACI 530.1, Specification for Masonry Structures

Wood Structures Design

American Forest & Paper Association, *National Design Specification for Wood Construction*

American Forest & Paper Association, *National Design Specification Supplement*

American Forest & Paper Association, *Manual For Engineered Wood Construction and Supplement*

Composite Material Design

ETL 1110-2-548, Composite Materials for Civil Engineering Structures

Bridge Design

American Association of State Highway Traffic Officials (AASHTO), *Standard Specification of Highway Bridges*

Florida Department of Transportation (FDOT), *Standard Specifications for Road and Bridge Construction*

Culvert Design

EM 1110-2-2902, Conduits, Culverts and Pipes

FDOT, *Standard Specifications for Road and Bridge Construction*

Concrete Channel Design

EM 1110-2-2007, Structural Design of Concrete Lined Flood Control Channels

Pumping Station Design

EM 1110-2-3102, General Principles of Pumping Station Design and Layout

EM 1110-2-3104, Structural and Architectural Design of Pumping Stations

TI 809-02, Structural Design Criteria for Buildings

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Spillway Design

EM 1110-2-2400, Structural Design of Spillways and Outlet Works

EM 1110-2-2701, Vertical Lift Gates

Retaining Wall Design

EM 1110-2-2502, Retaining and Flood Walls

EM 1110-2-2504, Design of Sheet Pile Walls

TR-01-1, State of the Practice in the Design of Tall, Stiff, and Flexible Tieback Retaining Walls

Closure Structure Design

EM 1110-2-2705, Structural Design of Closure Structures for Local Flood Protection Projects

Standard Details and Guideline Drawings

7.3 Project Implementation Report (PIR)

7.3.1 Alternatives Evaluation

General Requirements

The Alternatives Evaluation phase of the project is for the collection of information and data necessary to develop conceptual plans and costs for an evaluation and comparison of design alternatives. The evaluation of alternatives will identify those that are constructible and the degree that the respective design meets the safety, reliability, technical, functional, operational, and maintenance requirements and objectives.

The following guidelines shall be utilized for preparing structural input during the Alternative Evaluation phase.

The structural engineer shall:

1. Collect, from the Project Delivery Team (PDT), the following information:
 - a. A description of the structural feature(s) for each alternative with pertinent hydraulic/hydrologic data for each structure.
 - b. A description of the geology at each structure, preliminary soil parameters, and guidance on soil characteristics such as approximate bearing capacities and groundwater levels.
 - c. Topographic survey data for each project site.
 - d. Use of the structure (e.g., flood control, water supply, and environmental restoration).

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2. Be responsible for identifying all functional design requirements and technical design criteria for the structural elements of the project. These include all design data obtained through coordination with other disciplines (e.g., machinery loads and layout).
3. Be responsible for the production of a preliminary conceptual plan and a typical section of each structure included in the alternatives evaluated.
4. Coordinate conceptual designs with the civil-site engineer and cost estimator for preparation of site plans and cost estimates respectively.
5. Prepare a written description of the technical basis for selection of type and configuration of main and major appurtenant structures included in the alternatives studied.
6. Prepare a written description of the probable construction techniques and sequencing, plans for dewatering and care of water (e.g., cofferdams and diversion walls), and possible site restrictions for the structures included in the alternatives studied.
7. Participate in appropriate PDT activities, including site visits.
8. Solicit input on the conceptual designs and incorporate these comments through revisions as appropriate.
9. Refer to Standard Guideline Drawings and Details in the formulation of alternative plans as appropriate.

Required Documentation/Products

The report plates and structural descriptions shall be presented in the engineering appendix to the PIR. All views presented in the report plates shall be prepared as electronic CADD files in accordance with the requirements of Graphic Presentation, Section 2 of this manual.

7.3.2 Design of Tentatively Selected Plan

General Requirements

During this phase of the project, all significant structural design issues shall be resolved in accordance with ER 1110-2-1150. The design of the structural features in the Design of Tentatively Selected Plan (TSP) shall be developed to a level required to ensure that they can be presented in contract plans and specifications without the need for major revisions. The design performed must also be sufficient to ensure that reasonable costs can be developed for preparation of a detailed baseline cost estimate.

Information presented in this section is organized within four subcategories: Design Guidelines/Considerations, Design Criteria, Special Requirements, and Required Documentation. The Design Guidelines/Considerations section outlines the expected design efforts that shall be performed by the structural engineer. Additionally, this section describes some of the considerations, arranged according to feature type, which shall be examined during the TSP phase. The Design Criteria section provides a detailed listing of typical structural analysis methods, design values, bolted connections, and coatings used for CERP projects. Within the Special Requirements section are design considerations that are applicable to projects located

near waterways. The Required Documentation section provides direction for the presentation of data acquired during the TSP phase.

Design Guidelines/Considerations

The following guidelines shall be utilized for preparing structural input during the TSP phase. The structural engineer must exercise judgment with these guidelines and determine the appropriate level of effort necessary to satisfy the objectives stated previously for this design phase.

The structural engineer shall:

1. Provide results of stability analyses to show application of stability criteria, methods of analysis, and assumptions for each type of structural monolith. Flotation analysis may be necessary for gated culvert structures and other water control structures.
2. Provide results of initial stress analysis to show application of strength criteria, methods of analysis, assumptions, and key dimensions of components of each major structural system.
3. Provide results of initial seismic analysis to show application of seismic criteria, methods of analysis, assumptions, and key dimensions of components of each major structural system required to meet seismic requirements (refer to the Design Criteria section for further information regarding seismic design criteria).
4. Describe the results of any analyses, laboratory tests, or field tests, which were necessary to evaluate unusual site conditions, operating environments, material availability, or load levels (e.g., a concrete materials report).
5. Identify any significant unresolved design issues and make recommendations to address them. For example, a type, size, and location engineering study may be required to identify a cost-effective conveyance structure located underneath a highway. An evaluation of structural alternatives such as this shall be initiated upon commencement of the TSP.
6. Be responsible for the production of a detailed plan view, elevation view, and longitudinal and transverse section views of each structure. Additional views may include cofferdam details and a foundation plan if they are required. The structural engineer shall work with the civil-site engineer to develop a construction site plan and a final site plan for each structure.

The following considerations are typical for use in the design of structural features for CERP projects:

1. Retaining Wall Structures

The structural engineer is responsible for determining whether a rigid or flexible wall system is utilized for the retaining structure and for providing justification of this selection in the design documentation.

Sheet pile walls shall be designed in accordance with EM 1110-2-2504. For concrete retaining walls, the design shall be in accordance with the requirements of EM 1110-2-2502.

2. Pumping Stations

Pump stations shall be designed in accordance with EM 1110-2-3104. Depending upon the size of the station, components to be analyzed may include the foundation design, substructure, intake structure, upstream and downstream wingwalls, service bridges, operating floor, and superstructure. South Florida Water Management District (SFWMD) Guideline Drawings shall be followed as applicable.

The following considerations are employed in the a typical design process:

- a. Classification - Refer to Mechanical, Section 8 of this manual, for a description of small, medium, and large-sized pump stations.
- b. Superstructure - Pump station superstructures are not considered hydraulic control structures and shall be designed in accordance with ACI 318. Large and medium-sized pump stations shall be fully enclosed and include both an office and a restroom. Concrete or steel framing systems shall be considered for the enclosure. Avoid use of masonry block construction for the superstructure except on small-sized stations. Temporary pump stations (service life ten years or less) shall be covered with a roof system. Consideration for pump and equipment vibration and isolation shall be made for the design of pump station structures.
- c. Roof - Large and medium-sized pump stations, primarily used for flood control, generally will not require roof hatches for servicing and removal of pump equipment. Small, unmanned flood control or water supply stations may require roof hatches. Where roof hatches are used, the facility shall be designed with respect to the type of crane that shall be used for the pump extraction. For stations with engine exhaust stacks, a 3-ply modified bitumen roofing system shall be used to resist damage from hot particles.
- d. Substructure - Concrete substructures are considered hydraulic control structures and shall be designed in accordance with EM 1110-2-2104. Configurations for intake (rectangular versus formed suction intake) and discharge depend on the pumping capacity per bay. Refer to Mechanical, Section 8 of this manual, for selection of configurations. Concrete investigations, to identify mix designs and placement methods, shall be performed for all designs that include mass concrete.
- e. Intake and Discharge Structures - Large and medium-sized pumping stations will generally be separate monoliths upstream and downstream of the substructure designed in accordance with EM 1110-2-2104. These structures allow each bay to be dewatered using a system of aluminum dewatering needles resting against a dewatering beam that is installed in wall recesses. In general, the stability analysis considers only one bay dewatered at any time. For access, a service bridge (minimum width of 14 feet) will generally be constructed across the intake structure. The service bridge shall be designed for an American Association of State Highway and Transportation Officials (AASHTO) HS-20 service load, or other loads as defined by the end user. The design shall be checked for Florida legal SU-3 and SU-4 truck loads which may be anticipated during construction. Trash racks shall be designed for five feet of differential head.

3. Bridges

The design of bridges for public use shall satisfy AASHTO and Florida Department of Transportation (FDOT) standards, including maintenance of traffic criteria. Design progression should agree with FDOT standards, including a concept study, bridge development report, and design phase milestones. Vertical alignment alternatives will satisfy drainage/exposure vertical clearance requirements. For conventional bridges, arrangements of superstructure depth, span arrangements, and bridge sections shall be considered. For culvert bridges, arrangements of pre-cast concrete bridge systems shall be considered. Selected designs should include the combination of maintenance of traffic, roadway modifications, structure requirements, and impacts to existing structures that produce the least total construction costs based on acceptable levels of safety and disruption to the motoring public. Selected designs should also include a utility relocation plan, indicating the type and ownership of all existing utilities. Components to be analyzed may include the foundation, piers, abutments, and superstructure.

4. Spillways

Spillways shall be designed in accordance with EM 1110-2-2400. For hydraulic control structures, the concrete shall be designed in accordance with EM 1110-2-2402. These structures allow each bay to be dewatered using a system of aluminum needles resting against a dewatering beam that is installed in wall recesses. In general, the stability analysis considers only one bay dewatered at a time. For access, a service bridge (minimum width of 14 feet) will generally be constructed across the structure just downstream of the vertical lift gate. The service bridge shall be designed for an AASHTO HS-20 service load or other loads as defined by the end user. The design shall be checked for Florida legal SU-3 and SU-4 truck loads that may be anticipated during construction. Components to be analyzed may include the foundation design, gate monolith, stilling basin, service bridge, vertical lift gate, operating platform, and upstream and downstream wingwalls.

5. Buildings

Pre-engineered concrete buildings shall be utilized where practical. The overturning stability of these structures for high wind conditions shall be reviewed. For architectural requirements, see Architectural, Section 10 of this manual.

6. Culverts

Culverts shall be designed in accordance with EM 1110-2-2902. Components to be analyzed may include the foundation, culvert structure, headwalls, wingwalls, discharge basins, walkways, and gates.

- a. Pipe Type - For construction in-the-dry, culverts shall be reinforced concrete pipe. For construction in-the-wet, culverts shall be corrugated aluminum pipe. Operating platforms, when required, shall be aluminum railing, decking, and framing mounted to steel H-piles. The H-piles shall be coated with coal tar epoxy to provide a level of corrosion resistance. Dewatering requirements for maintenance of gates are typically not required. Dewatering requirements for maintenance of gates are typically not required. Where possible, the use of a precast gate enclosure should be utilized to provide secure access to the gates. For culverts passing through levees, the enclosure can be located near the levee crest to provide personnel access.

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- b. Box Type - Pre-fabricated concrete box culvert systems shall be utilized where practical. The ends of the box culvert will typically consist of a headwall with straight wingwalls and slots on each side so the structure can be de-watered for maintenance.

7. Cofferdams

Cofferdams, where required for temporary construction dewatering, shall be designed using steel sheet piles in accordance with EM-1110-2-2504. In general, a detailed cofferdam design shall be prepared and presented in the contract documents when it is required for dewatering. This design will consider load cases that can occur during excavation and dewatering and will clearly specify when cross bracing is required to be installed or can be safely removed after construction is complete. When tremie concrete is placed to seal the bottom of the cofferdam, consideration shall be given to reducing the tremie thickness required by utilizing anchors to resist uplift forces. When cofferdams are required for the dewatering plan, components to be analyzed include the steel sheet pile walls, wales, and struts.

Design Criteria

The criteria described below are considered typical for application in the design of structural features for CERP projects. Exceptions to criteria may be required for certain design situations.

1. Load Combinations

Structures, components, and foundations shall be designed so that their design strength equals or exceeds the effects of the factored loads in ASCE 7. If load combinations are prescribed in an applicable engineering manual, then the load combinations shown in the engineering manual takes precedence over ASCE 7.

2. Stability

For the purpose of establishing safety factors for use in stability analyses, structures are designated as either critical or normal. Structures are designated as critical if their failure will result in loss of life. If the effects of a structural failure are unknown, then an inundation study may be required to classify the downstream hazard. Additional guidance on the classification of downstream hazards is provided in ACER Technical Memorandum No. 11.

3. Wind Design

Wind loads for the design of the main wind-force resisting system and for components and cladding shall be determined using the provisions of the most recent edition of ASCE 7.

- a. Wind Speed (V) – Basic sustained wind speed determined from Figure 6.1 of ASCE 7.
- b. Level of Importance (I) – For critical structures that are occupied during or are required to operate in a hurricane condition, a category III importance factor of 1.15 shall be used. For all other structures, the importance factor is 1.0 (category II) shall be used.
- c. Mean Recurrence Interval (MRI) – For the control room of a pumping station or other facility that is manned during a hurricane, a MRI of 500 years shall be applied. All structural elements shall be evaluated for effects of hazards, from elements within

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proximity of the control room, and should adopt the more stringent design criteria. For structures that are designated flood control structures and are required to operate during a hurricane, a MRI of 200 years shall be applied. This includes the flood control structure's control building. For water control structures that are not required to operate during a hurricane, which may include but not limited to seepage control and water supply structures, a MRI of 50 years shall be applied.

- d. Wall openings – For structures that have been designed for a MRI of 200 years or greater, rolling doors, fans, windows, ducts, and louvers shall be designed to meet the building envelope protection requirements of the Florida Building Code, Test Protocols for High Velocity Hurricane Zones. Additionally, all items shall meet this requirement for components and cladding. Single or double doors shall meet the requirements of FEMA 361. For structures that have been designed for a MRI of 50 years, fans, ducts, and louvers shall be designed to meet the requirements of the Florida Building Code. All exterior doors shall be steel.

4. Seismic Design

The Department of Defense will adopt the provisions of IBC 2000 to calculate seismic loadings for pumping station superstructures and other structures. Normally, seismic loads will not be significant for CERP projects in Florida.

5. Concrete Design

General criteria for concrete shall be in accordance with EM 1110-2-2000 and ACI 318.

- a. Load Factors – Load combinations and strength design factors for hydraulic concrete structures shall be in accordance with EM 1110-2-2104. Load combinations and strength design factors for all other concrete structures shall be in accordance with the most recent edition of ASCE 7.
- b. Design Values – Typical design values are as follows:
 - Mass Concrete – $f'_c = 2500$ psi @ 28 days.
 - Structural Concrete – $f'_c = 3000$ to 4000 psi @ 28 days.
 - Prestressed Concrete - $f'_c = 5000$ psi @ 28 days.
 - Steel Reinforcement - $f_y = 60$ ksi.

6. Steel Design

General criteria for steel shall be in accordance with EM 1110-2-2105 and AISC.

- a. Load Factors – Load combinations and strength design factors for hydraulic steel structures shall be in accordance with EM 1110-2-2105. Load combinations and strength design factors for all other steel structures shall be in accordance with the most recent edition of ASCE 7.

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b. Design Values – Typical design values are as follows:

- Structural Steel – A 572, Grade 50.
- Corrosion Resisting Steel – Type 304 (freshwater) and 316 or 317L (saltwater).
- Sheet Piles – Normally type A 328 or A 572 (grade 50), hot rolled for permanent structures. Cold rolled sections (A 328 or A572) may be used for temporary structures including bypass walls.

c. Bolted Connections – Structural steel connections normally type A325 Type I, or A490 Type I. Submerged connections (i.e., gate seals) normally CRES bolts with Armco Nitronic 60 nuts.

d. Coatings – Normally, components that shall be exposed to the elements are either hot-dipped galvanized or painted with coal tar epoxy. Vertical lift gates and steel sheet pile structures may be painted with a vinyl paint system.

Special Requirements

The following design considerations may be identified as necessary at some sites:

1. Manatee Barriers – Designed to prevent entrance of manatees into culverts or spillways. Barrier designs will vary depending on specific site conditions. The design should include provisions for removal of the barrier(s) to allow for cleaning and routine maintenance.
2. Debris/Safety Barriers – Designed to prevent boaters, floating vegetation, and debris from entering structures. Barriers are normally floating type installed with galvanized wire cable and pressure treated timber piles. Other barrier designs may include mechanized trash cleaning racks installed upstream of structures on a steel frame with H-pile supports.

Required Documentation

The report plates and structural descriptions shall be presented in the Engineering Appendix to the PIR. All views presented in the report plates shall be prepared as electronic CADD files in accordance with the requirements of Graphic Presentation, Section 2 of this manual.

7.4 Plans & Specifications

General Requirements

Plans & Specifications (P&S) shall be prepared in accordance with ER 1110-2-1200 and applicable CADD standards presented in Graphic Presentation, Section 2 of this manual.

As outlined in ER 1110-2-1200,, the Pre-construction Engineering and Design phase (PED) is the phase during which the design is finalized, the P&S are prepared, and the construction contract is prepared for advertising. Structural products produced during the PED phase are subject to an Independent Technical Review (ITR) to ensure the designs conform to proper criteria, that any deviations to criteria or scope are properly justified, and that appropriate design methods have been followed.

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The following guidelines shall be utilized for preparing structural input during the P&S phase.

The structural engineer shall:

1. Collect the following information from the PDT:
 - a. Final hydraulic/hydrologic data for each structure, including pool surfaces and hydraulic jump profiles if applicable.
 - b. Final soil design parameters and copies of the core boring logs.
 - c. Final topographic surveys of project sites including contours and spot elevations.
2. Identify and/or verify all sponsor requirements, functional design requirements, and technical design criteria to be used for this work.
3. Complete all design analysis of components not performed during the TSP phase. The analysis shall be checked by another structural engineer in the design office to verify that all design assumptions and calculations are correct.
4. Prepare contract drawings utilizing designs developed for the PIR.
5. Prepare all contract specifications as related to the structural features for the identification of all structural submittal requirements in the submittal register.
6. Coordinate all work related to the structural design and participate in all PDT activities to ensure design continuity.
7. Prepare input for the Engineering Considerations and Instructions (ECI) for field personnel, as discussed in ER 1110-2-1150. This document will provide field personnel with insight on unique aspects of the work as well as background information about the design intent.
8. Address all review and bidder comments and incorporate them into the contract documents as applicable.